# IOWA

# GEOLOGICAL SURVEY

BULLETIN NO. 2.

## A Preliminary Report on the Peat Resources of Iowa

AND

## A Report on the Tests of Iowa Coals Made by the Government Coal-Testing Plant at the Louisiana Purchase Exposition, St. Louis, Mo., 1904

FRANK A. WILDER, PH. D., STATE GEOLOGIST.
T. E. SAVAGE, ASSISTANT STATE GEOLOGIST.

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PUBLISHED FOR IOWA GEOLOGICAL SURVEY
1905

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# A PRELIMINARY REPORT ON THE PEAT RESOURCES OF IOWA.

BY

T. E. SAVAGE.

## INTRODUCTION.

For several years it has been known that considerable quantities of peat existed in the marshes of northern Iowa. As early as 1867 Dr. Charles A. White made some observations on these deposits and called attention to their importance.*

In the present series of Geological reports the presence of peat is noted in a few counties, but no attempt was made to determine the extent or the quality of such beds.

In recent years the increase in the cost of fuel and, especially, the improvement in the methods and the machinery by which peat is prepared and utilized, have so stimulated the development of the peat industry that such deposits promise to become important sources of heat, light and power.

For some time the Director of the Iowa Geological Survey has been planning a systematic study of the peat deposits of the state, but until recently this has been deferred owing to the pressure of other lines of work that seemed to be more imperative. However, the investigation was taken up during the summer of 1905, and the field work was assigned to Mr. L. H. Wood, under the supervision and with the assistance of the State Geologist.

A thorough examination of the individual marshes was undertaken to locate those that were productive, to learn the extent and the depth and the quality of the peat which they contain, and to collect samples from the several deposits from which analyses and tests could be made.

The marshes of the state proved to be richer in vegetable deposits than was anticipated. In view of the large quantity of peat that was located, and because of the growing importance of this industry, it was thought desirable to publish a general report on the peat resources of the state in the form of a bulletin, preliminary to the more complete report which will embody the results of the analyses and tests that are yet to be made.

The data relative to the distribution, location and description of the peat-bearing marshes are taken from notes made by Mr. Wood. Many of the facts relating to the manufacture of peat fuel, and cost of machinery were obtained from a paper by W. E. H. Carter in the Twelfth Report of the Ontario Bureau of Mines, and from Special Consular Reports, Volume XXVI, which treats of Briquettes as Fuel in Foreign Countries.

*White: 1st and 2nd Annual Reports of Progress, pp. 121-135. 1868.
See also, Geol. of Iowa, Vol. 2, pp. 275-288. 1870.

## COMPOSITION OF PEAT.

Peat represents the early stages in the carbonization of vegetable matter, just as coal is the product of a more advanced stage of this same process. It is composed of plant tissues that have undergone more or less decomposition and chemical alteration. It varies from a yellowish or brown, fibrous substance in which the leaves and tissues of the plants are quite perfectly preserved, through different stages of decay and maceration, to a dark colored, mucky material in which little of the original structure can be recognized.

There is always present in the peat a variable amount of mineral matter. This material may represent the ash or mineral constituents of the plants from which the peat was formed, or it may consist in large part of foreign matter derived from the silt borne by winds or from sediments carried by water.

In the natural state peat always contains a high percentage of moisture which is with difficulty removed by drying.

In Iowa marshes a large proportion of the vegetable matter is in a more or less fibrous condition. It is in part composed of the remains of aquatic species of mosses belonging to the genus Hypnum, but in most of the bogs the leaves and stems of rushes, sedges and other groups of water-loving plants have contributed the larger share.

The following analyses will show the composition of samples of Sphagnum moss, oak wood, New Jersey peat and Illinois coal. The table also shows the gradual increase in the percentage of carbon that takes place in the changing of the vegetable matter to peat, and in its further alteration to bituminous coal.

*Comparative Table Of Analyses*

| Material | Carbon per cent. | Hydrogen per cent. | Oxygen per cent. | Nitrogen per cent. |
|---|---|---|---|---|
| *Sphagnum moss | 49.88 | 6.54 | 42.42 | 1.16 |
| *Oak wood | 50.60 | 6.00 | 42.10 | 1.30 |
| *New Jersey peat | 58.00 | 6.36 | 31.85 | 1.14 |
| †Illinois coal | 65.48 | 5.09 | 15.04 | 1.39 |

The close similarity between the composition of Sphagnum moss and oak wood will appear from the table, and the decrease in the proportion of oxygen as that of the carbon content increases will also be observed. The best grades of peat contain 10 to 12 per cent more of carbon and 10 to 12 per cent less of oxygen than the vegetable matter from which it was formed.

## CONDITIONS OF PEAT ACCUMULATION.

In order that vegetable matter may be preserved in the form of peat the material must accumulate under water where it will undergo imperfect decomposition without free access of air. When plants decay on the surface of the ground the tissues are soon broken down into the

*Ries: 21st Report of the State Geologist of New York, pp. 58 and 61, 1901.
†See this bulletin, p. 28.

simple compounds out of which the vegetable structures were built, and the materials are returned to the air in the form of carbonic acid gas, water and ammonia. The humus of the soils and the leaf mould of the forests represent the products of incomplete oxidation or decay of organic matter on the surface of prairie and woodland.

Under water, where the supply of oxygen is limited, decomposition of vegetable matter is much less rapid and complete. In the water containing such matter there are also present soluble acids whose antiseptic properties serve further to hinder the process of plant decay. Under these circumstances small quantities of carbonic acid gas, marsh gas and nitrogen are slowly liberated, but there are left much of the hydrogen and the greater portion of the carbon. The further such decomposition proceeds the higher is the proportion of carbon that remains, as is shown in the foregoing table.

Conditions favorable for the accumulation of peat are usually present in swamps or marshes or around the margins of small lakes or ponds. In such places the vegetation is usually luxuriant, and as the successive generations of plants die their stems and leaves fall in the water and are there protected from complete decay.

## MANNER OF ACCUMULATION OF IOWA PEAT BEDS.

When the glaciers melted from our state they left a comparatively level surface which was broken by numerous minor inequalities. Depressions of varying extent and depth dotted the prairies, and were especially abundant over a belt near the margin of the respective ice sheets known as the terminal moraine. Such basins became filled with water and formed lakes and marshes which are still conspicuous topographic features of northern Iowa. Such bodies of water are quite free from sediments, and furnish congenial conditions for the growth of a large variety of plants.

Marsh-loving forms soon established themselves around the shallow margins of these pools, and lowly algae flourished in the deeper water. Aquatic mosses spread widely over the surface in tangled mats and long, floating strands. As the growth of each year was completed the dying leaves and stems and filaments fell to the bottom and were embalmed together by the water of the bogs. As the seasons of the centuries came and went the water was constantly shallowed and the borders of the basins were constantly narrowed by the accumulation of plant remains. The grasses and sedges kept crowding each other further out from the shore, the amphibious rushes pushed out further still, while among and beyond these the water-loving mosses reached constantly toward the center. As the deposit deepened the alteration of the materials continued and the vegetable matter became more and more compacted into peat.

The rate of accumulation of these deposits depends largely upon the character of the vegetation which the marsh supported. Where the plants consisted chiefly of species of mosses the increase was made very slowly, but where the deposit is made up of the remains of coarser

plants, the accumulation grew more rapidly. The stage of filling at present attained in the lakes of our state depends also upon the size of the lake and the original depth of the basin.

In north-central Iowa, lake filling by the accumulation of vegetable debris has been in progress ever since the retreat of the Wisconsin glacier. At the present time the history of many of the smaller lakes and marshes has been completely closed; areas of swamp soil being the only witnesses to the former existence of water, and the only indication of underlying deposits of peat.

In other lakes the filling is but partially completed, and they exist today as broad, shallow marshes overgrown with moss and rush and sedge, whose stems and leaves still contribute an annual increment to the vegetable accumulation on the bottom.

In the larger and deeper lakes, where wave action was stronger, there are no deposits of vegetable matter or but a discontinuous fringe which represents the initial deposit of a future bed of peat.

## DISTRIBUTION OF PEAT MARSHES IN IOWA.

The peat deposits of Iowa occur in the north-central portion, over the area that was covered by the Wisconsin ice sheet. They are especially well developed in a belt eight to twelve miles in width around the margin of this area, among the ridges of the moraine. In such situations the water level of the lakes is held higher and more constant than over the level lands. The basins also are deeper, thus preventing a large proportion of mud being mixed with the vegetable material through the borings of crayfish. The gentle slopes that border the depressions were until recently covered with forests which protected the growing deposits from contamination by silt or sediments from wind or water. For these reasons the morainic basins generally contain deeper and purer deposits of vegetable matter than are found in the marshes over the prairies.

The greater number of good bogs occur among the hills of the Altamont moraine, on the eastern border of the Wisconsin drift plain. They cover areas of varying extent in the west half of Worth, Cerro Gordo and Franklin counties and the eastern portions of Wright, Hancock and Winnebago. Between this eastern belt and the west side of the Wisconsin drift area there are occasional marshes that contain considerable peat. The largest of these occur in the counties of Emmet, Palo Alto and Clay, while smaller areas are found in Dickinson, Kossuth, Green and Calhoun counties.

The quantity of peat in the Iowa marshes, distributed by counties, can be computed by multiplying the number of acres of peat-bearing marsh land in each county by the average depth of the peat in yards, on the assumption that one acre of peat, three feet in depth, would produce 1,000 tons of dried fuel.

On this basis Worth county should yield in round numbers 6,000,000 tons of dry peat fuel; Winnebago county 8,000,000 tons; Hancock county 3,000,000 tons; Cerro Gordo county 10,000,000 tons; Wright

county 1,000,000 tons; Franklin county 1,500,000 tons; Emmet county 2,000,000 tons and Clay and Palo Alto counties 4,000,000 tons.

If we would be very conservative and estimate the yield of peat per acre, three feet in depth, at only 600 tons* of dried fuel, we would still have about 22,000,000 tons of such fuel located in northern Iowa.

The distribution of the marshes, and their relation to the border of the Wisconsin drift sheet are shown on the accompanying map.

## LOCATION AND DESCRIPTION OF INDIVIDUAL MARSHES.†

### PEAT DEPOSITS IN WORTH COUNTY.

The peat-bearing marshes of Worth county occur in the townships of Fertile, Bristol, Silver Lake and Hartland.

*Fertile township area.*—About two miles west of Hanlontown, in the southern portion of Fertile township, is a large marsh known as Goose lake. It lies partially in sections 21, 22, 26, 27 and 28, and covers an area of from 600 to 800 acres. Two test borings at widely separated points showed a depth of 12 and 13 feet, respectively, of clean, fibrous, fairly dry vegetable matter.

Near the west side of this same township a marsh, 150 to 180 acres in extent, covers portions of sections 18, 19 and 30. A boring near the middle of section 19 showed a depth of 8 feet of peat.

In the northeast corner of Fertile township, and extending across section 7 of Danville, is a broad slough that embraces 160 to 200 acres, and contains a depth of 13 feet of clean, solid peaty material.

The above marshes and others of smaller extent, make Fertile township a rich center for peat. They could all be worked from Hanlontown, the nearest railroad station from which the most distant bog is about five miles.

Rice lake, in Bristol township, is bordered with vegetable deposits some of which are very deep. At the east end there is an area of 200 acres in which the deposit tested 12 feet in depth. An arm of this lake covering several hundred acres extends towards the southwest into Winnebago county.

Two and one-half miles east of Joice a marsh covering 50 acres tested 7 feet of solid peat, and another good deposit lies nearer to the town.

The larger marshes of Bristol township are convenient to the Lake Mills area, in Winnebago county.

*Northwood area.*—In Hartland township a narrow slough extends for three miles along a creek in sections 33, 34 and 36. This area embraces more than 200 acres and tested 9 feet in depth. Along Goose creek, in sections 13, 14 and 15, a marsh nearly as large as the last tested 3 to 10 feet of vegetable material. This deposit is somewhat scattered along the creek but might become valuable if worked

*Trans. Am. Inst. of Mining Engineers, Vol. XXXV. p. 101. 1905.

†A sufficient number of borings to determine the average depth of the vegetable material in the different marshes could not well be made. However, the figures given represent actual measurements taken, and it is believed that they will be a fairly reliable guide with regard to the relative thickness of the peat deposits in the several marshes.

in connection with the very large area around Grass lake, a short distance north of the state line.

*Norman area.*—A large quantity of peat covers the bed and fringes the border of Bright lake, within one mile of the town of Norman. A small marsh in section 36 of this township also contains a good depth of peat. A boring in the marsh at the east end of Silver lake passed through 13 feet of vegetable debris.

### PEAT IN WINNEBAGO COUNTY.

One and one-half miles southwest of Norman, a grass-grown slough, covering between 200 and 250 acres in section 14 of Norway township, tested 5 feet of dense, brown colored peat.

*Scarville area.*—A marsh about one mile southwest of Scarville covers nearly 200 acres in section 22 and 23 of Logan township, and contains peat 7 feet in depth. South of Harmon lake, in section 21, a small marsh covers 50 acres, and at the north end of the lake, in sections 20 and 21, is another nearly equal in size. Both of these contain a good depth of vegetable debris.

Two miles southeast of Scarville a swampy area lying north of the railroad includes portions of sections 20, 21, 27 and 28 in Norway township. This marsh is not uniform in depth, but borings in section 28 showed a depth of 6 to 15 feet of peaty matter.

*Lake Mills area.*—The thriving town of Lake Mills, in Center township, is fortunately located for the production of peat. Swamps aggregating 800 to 1,000 acres surround the town at a distance of from one to three miles, and two lines of railroad afford good facilities for distributing the product.

In section 34 and 35 of Norway township, a marsh covers 200 acres and tested 10 feet of peat. A bog of 100 acres, in section 1 of Center township, extends east into Worth county, and tested 13 feet of accumulated vegetable matter. Marshes in sections 3 and 4, about one mile west of town, aggregate nearly 300 acres and showed peat to a depth of 8 to 15 feet.

A filled lake basin extends from the south end of lake Greeley to the west end of Rice lake. A few wooded islands occur over this marsh but the greater portion of the area is covered with a deposit of peat which, near the east end, tested 13 feet in depth. A marsh that lies across section 26 of Center township, in a northeast-southwest direction, represents the northeastward extension of Walnut lake. Near the middle of this swamp a boring passed through a depth of 13 feet of peat. Southeast of Walnut lake a marsh extends for two miles, invading the northeast corner of Mount Valley township. In section 1 of the latter township, a marsh covering 40 acres showed a maximum depth of 10 feet of vegetable matter.

Another swamp, embracing nearly 80 acres, covers a portion of sections 2 and 3 of the latter township and of section 34 of Center. This area tested 9 feet of peat. All of the marshes of Center township and those in the northeast corner of Mount Valley belong naturally

to the Lake Mills area. In the process of excavating the peat a waterway could, with little expense, be opened to the northward from the latter marshes above described through those between Walnut lake and Rice lake and on through the bogs connecting Rice lake with lake Greeley. Through such a channel the peat from several hundred acres of swamp land could be brought to Lake Mills by water and there prepared for shipment.

*Forest City area.*—About five and one-half miles northeast of Forest City, a marsh covers nearly 200 acres in sections 16 and 17 of Mount Valley township. A boring towards the north side of this marsh showed 10 feet of clean, solid vegetable material. Other marshes, together covering more than 100 acres, in sections 28 and 33 of this township, showed a depth of 13 feet of plant debris. This latter area consists of narrow bogs separated by north and south ridges of morainic material. The peat seems to be very pure and the bogs are fairly dry.

Near the south side of section 32, Forest township, a marsh covers more than 100 acres and contains a depth of 3 to 4 feet of vegetable matter. There are other scattered bogs of small extent in this portion of the county.

Among the hills in sections 24 and 25 of Mount Valley township there is an irregular basin over which marshes cover an aggregate of 100 acres, and show a depth of 6 to 15 feet of peaty matter. This latter area would be most successfully worked in connection with the Goose lake marsh in Worth county.

*Thompson area.*—A series of small swamps, separated by wooded ridges, occur in sections 1 and 12 of King township and sections 7, 8 and 17 of Newton. Together these cover more than 300 acres, and show a depth of 4 to 10 feet of peat which is dry, firm and very pure.

### MARSHES IN HANCOCK COUNTY.

Many of the larger marshes of the county occur over level prairies and contain but shallow deposits of impure peat.

*Kanawha area.*—Two miles northeast of Kanawha a large marsh covers 160 acres, in sections 22 and 23 of Amsterdam township. Borings over this area showed 3 to 4 feet of vegetable matter, while a well towards the north edge of the marsh is reported to have passed through 8 feet of peat.

A short distance south of East Twin lake a cat-tail slough covers a portion of section 29 and crosses section 32 of Twin Lake township. Tests near the margin indicated a depth of 3 to 5 feet of peaty matter. Much of this swamp is very wet, but the water could be drawn off to the eastward through the west branch of Iowa river into which stream the area has already been partially drained.

*Duncan area.*—About one mile southeast of the town of Duncan a large marsh of 600 acres covers a portion of section 33 of Garfield township and of sections 4 and 9 of German. A ditch through this swamp drains the water to the southward. In the sides of this ditch good, clean peat is exposed to a depth of 3 to 6 feet. A small deposit

of peat also occurs along the east side of Eagle lake.

*Miller area.*—An unusually good deposit of peat occurs in a narrow slough one and one-half miles southeast of the town of Miller. The bog covers 200 acres and tested 10 feet of clean vegetable matter.

A marsh is reported near the northeast corner of Concord township, and small bodies of peat also occur along the east branch of Iowa river between Miller and Hayfield Junction.

### PEAT DEPOSITS IN CERRO GORDO COUNTY.

Practically all of the marshes of Cerro Gordo county lie in the west tier of townships. They are surrounded by low, morainic hills, 20 to 50 feet in height. They are generally well drained, and contain peat deposits that range from 3 to 15 feet in depth. The peat is uniformly clean and solid, and appears to be of excellent quality.

*Clear Lake area.*—The city of Clear Lake is situated in the midst of a rich deposit of peat. In section 26 of Clear Lake township an ice formed embankment[1] has cut off a southward extending arm from the main body of the lake. Over this area a marsh, covering more than 80 acres, occupies portions of sections 26 and 35. Tests in this bog showed 10 to 12 feet of black peat. A short distance further south a drained marsh, 250 acres in extent, covers the southern portion of section 35 of Clear Lake township and section 2 of Union. Borings over this area showed a depth of 5 to 6 feet of vegetable matter. Still further south a swamp covers 300 acres in sections 11, 12, 13 and 14 of Union township; and another marsh about equal in extent occupies a portion of section 24. The last two bogs are fairly dry and contain exceptionally pure deposits in which tests showed solid peat 12 feet in thickness. In the southwest ¼ of section 23 is a drained marsh, 60 to 80 acres in extent, that tested 7 feet of clean peat.

About one mile south of Clear Lake city, an ice formed wall separates another large marsh from Clear lake. From this ridge a bog extends nearly three miles towards the southeast, covering nearly 600 acres. Borings near the north end of this marsh indicated a depth of 3 feet of vegetable matter and it is probable that the thickness increases further south.

One and one-half miles north of Clear Lake a large marsh, 400 acres in extent, occupies a portion of sections 1 and 2 of Clear Lake township and of sections 34, 35 and 36 of Grant. This marsh is well drained, and contains a fine deposit of peat that tested 5 to 7 feet in depth. From the southwest ¼ of section 34 a narrow slough extends two and one-half miles towards the southwest, and contains a good depth of peat. In the west half of section 6, Clear Lake township, a marsh, connecting with bogs in Hancock county, covers nearly 80 acres, and showed a depth of 6 to 10 feet of peat. A smaller marsh in section 29 of Grant township contains a good deposit. A large swamp covering 400 acres, in sections 21, 22 and 27 of Grant township,

[1]For an explanation of the manner in which these embankments were formed see Iowa Geol. Survey, Vol. VII, p. 135.

tested 7 to 9 feet of vegetable matter, and a smaller one of 160 acres, in section 15, showed 5 feet.

A marsh of 200 acres covers a portion of section 25, and contains an excellent deposit of plant remains, 12 feet in depth.

Near the northwest corner of Grant township a good bog is reported, and a few promising marshes are found further east in the township of Lincoln.

*Meservey area.*—About one mile northeast of Meservey, a drained marsh covers 60 to 80 acres in section 28, Grimes township. Borings over this area showed 8 to 9 feet of clean, solid peat.

A large marsh in sections 19 and 20 is tile drained, and tested 7 feet of pure vegetable debris. In section 3, a marsh of 60 acres showed 5 to 7 feet of peat. The peat deposits around Meservey are small, but in quality they rank among the best in the state.

### PEAT AREAS IN WRIGHT COUNTY.

*Clarion area.*—About five miles north of Clarion a grassy marsh, lying partly in section 1 of Lake township and partly in section 6 of Grant, covers nearly 100 acres, and contains clean vegetable material to a depth of 9 feet.

Small bodies of peat, a few acres in extent and 3 to 6 feet in depth, occur between the above mentioned marsh and Little Wall lake. Other small marshes lie within a short distance north and east of Cornelia; while vegetable matter 2 to 3 feet in depth fringes a portion of the east side of Elm lake.

*Dows area.*—One mile west of Dows a number of disconnected swamp areas, aggregating nearly 100 acres, occupy portions of sections 27, 34 and 35 in Blaine township. Borings at different points over this area showed 4, 8 and 9 feet of clean, almost dry peat.

About five miles southwest of Dows a bog of 80 acres has been drained and, at one time, put under the plow. Tests over this marsh indicated 5 to 9 feet of vegetable matter.

Large marshes occur in the northeast ¼ of Wall Lake township, but the peat is shallow and carries quite a large percentage of earthy matter.

### MARSHES OF FRANKLIN COUNTY.

About two miles northeast of Dows, and conveniently worked with that area, a swamp of 100 acres covers a portion of sections 20 and 28 of Morgan township. It contains peat of fair quality, ranging from 5 to 15 feet in depth.

Near the north side of Lee township a marsh known as the "Big Slough" covers several hundred acres. This area was not tested, but it is reported to contain a good deposit of peat.

### PEAT DEPOSITS IN EMMET COUNTY.

*Armstrong area.*—In the southern portion of Iowa Lake town-

About one mile north of Waupeton, Iowa, the following beds may be viewed:

GALENA-TRENTON EXPOSED NEAR WAUPETON, IOWA.

| | | Feet | Inches |
|---|---|---|---|
| 5. | Limestone, sub-crystalline, with oilrock partings | 12 | |
| 4. | Shale parting | ... | 4 |
| 3. | Limestone, similar to the above | 1 | 5 |
| 2. | Shale, blue with thin limestone partings | 5 | 7 |
| 1. | Limestone, heavy bedded | 5 | |

No. 2 was carefully sampled and analyzed and the result is given below.

| | |
|---|---|
| Silica | 50.69 |
| Alumina | 15.63 |
| Iron oxide | 4.83 |
| Calcium carbonate | 11.15 |
| Magnesium carbonate | 8.43 |
| Alkalies as $K_2O$ | 1.46 |
| Sulphur trioxide | 2.65 |
| Combined water | 4.64 |
| Moisture | 0.49 |

L. G. Michael, analyst.

The shale member appears to be rather unimportant on both sides of the river. Samples were selected from two points on the Wisconsin side of the river, near McCartney and Potosi. The section at the former place is about as follows:

SECTION EXPOSED AT McCARTNEY, WISCONSIN.

| | | Feet |
|---|---|---|
| 10. | Limestone, subcrystalline, with oil-rock partings | 12 |
| 9. | Limestone, crystalline, with calcareous shale parting below | 1 |
| 8. | Limestone, hard, subcrystalline, chocolate colored | ½ |
| 7. | Shale, blue | 2 |
| 6. | Talus slope | 5 |
| 5. | Limestone, bluish, crystalline, thinly bedded | 5 |
| 4. | Talus slope | 10 |
| 3. | Limestone, compact, fine-grained, thinly bedded | 7 |
| 2. | Talus slope | 13 |
| 1. | Limestone, buff to blue, heavy bedded, appears to be sandy on weathered surface | 6 |

The above section is very similar to the Spechts Ferry section. An average sample of the shale from the above section and also a sample from Potosi, Wisconsin, which exhibits an almost

identical assemblage of beds to those exposed at Spechts Ferry, were selected for analysis. The results are as follows:

| | McCartney. | Potosi. |
|---|---|---|
| Silica | 49.10 | 48.88 |
| Alumina | 17.15 | 14.54 |
| Iron oxide | 8.46 | 12.00 |
| Calcium carbonate | 11.04 | 8.58 |
| Magnesium carbonate | 2.85 | 3.15 |
| Sulphur trioxide | 1.69 | 1.26 |
| Alkalies as $K_2O$ | 3.62 | 6.43 |
| Combined water | 5.36 | 4.48 |
| Moisture | 0.91 | 1.30 |

L. G. Michael, analyst.

South of Spechts Ferry the Platteville limestone is well exposed at Zollicoffer Lake. The section is given below:

SECTION IN GULLY NEAR ZOLLICOFFER LAKE, NORTH OF DUBUQUE IOWA.

| | | Feet | Inches |
|---|---|---|---|
| 10. | Magnesian limestone in beds 8-10 inches; top undefined... | | |
| 9. | Upper calcareous shale (Galena limestone)..... | 1 | |
| 8. | Magnesian limestone or dolomite beds in 7-10 inch layers.. | 4 | |
| 7. | Thinner, coarser-grained, fossiliferous beds, containing calcite crystals, runs 1-4 inch beds..... | 2 | 6 |
| 6. | Thin-bedded fossiliferous limestone, somewhat coarsely crystalline at top, becoming more "glass-rock"-like lower down; beds 1-5 inches, wavy bedded, with thin scales of "oil rock" in partings..... | 5 | |
| 5. | Beds more like "glass rock", finer grained but otherwise similar to No. 6..... | 5 | 10 |
| 4. | Heavy bed of medium grained limestone with calcite crystals..... | 1 | 4 |
| 3. | Shale, blue, clayey with numerous argillaceous limestone partings..... | 8 | 1 |
| 2. | Hard, rather coarse grained beds running from 3-5 inches thick, appear to be slightly magnesian, but may be because badly stained and weathered..... | 6 | |
| 1. | Hard, finer-grained, wavy bedded limestone in beds 3-6 inches thick. Upper 5 feet is gradation from (2) but lower down it becomes very fine grained, almost a "glass rock" at bottom of exposure..... | 12+ | |

All of the members in the above section below number 8, the dolomitic beds, were carefully sampled and analyzed. The analyses are given in the table below. The samples are numbered in the table the same as in the section.

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|
| Silica | 8.02 | 6.79 | 50.22 | 3.85 | 4.54 | 3.26 | 8.28 |
| Alumina and iron | 5.78 | 4.61 | 12.45<br>9.08 | 6.03 | 2.54 | 0.83 | 4.67 |
| Calcium carbonate | 77.93 | 78.24 | 13.83 | 84.16 | 86.33 | 90.20 | 80.14 |
| Magnesium carbonate | 4.43 | 5.12 | 2.96 | 1.93 | 3.54 | 2.65 | 2.37 |
| Alkalies as $K_2O$ | ..... | ..... | 5.23 | | | | |
| Combined water | 3.18 | 3.28 | 3.81 | 4.23 | 2.62 | 1.84 | 2.17 |
| Sulphur trioxide | 0.22 | 1.74 | 1.16 | 0.64 | 0.22 | 1.64 | 2.60 |
| Moisture | 0.16 | 0.04 | 1.71 | 0.03 | 0.08 | 0.06 | 0.13 |

L. G. Michael, analyst.

All of the beds carry some magnesia but not in prohibitory amounts. Number 2 carries the most, approximating two and a half percent of magnesium oxide. The entire section is above the tracks of the Chicago, Milwaukee & Saint Paul railway.

The pure limestones and shales in all of the sections given thus far are well above the railways of the vicinity and numerous exposures are directly on the railways, and near the Mississippi, so that cheap transportation would be assured in case the Platteville is developed commercially. The dolomitic portion of the Galena-Trenton overlies the shales and limestones in the bluffs, but considerable areas are available where the overburden has been removed or at least has been reduced to an almost negligible thickness. At any of the above sections both the limestone and the shale could be mined easily by drifting directly into the bluffs. The scarcity of the shale is something of a drawback, but by no means as serious as might at first thought be supposed. Maquoketa shales of considerable thickness outcrop at no great distance inland. Good sections are exposed at Kidder and Graf, along the Chicago Great Western, and at Peosta along the Illinois Central railway. Thesection exposed near Graf is given below.

| | | Feet | Inches |
|---|---|---|---|
| 5. | Shale, drab and black, unfossiliferous | 2 | |
| 4. | Shale, brownish, hard, granular, non-fissile and fossiliferous | 1 | 2 |
| 3. | Shale, drab, fissile, non-fossiliferous | 1 | 4 |
| 2. | Shale, variable in color, texture and fissility, with fossiliferous bands | 11 | |
| 1. | Shale, brown or black, non-fissile, fossils rare | 6 | |

An analysis of the shales developed near Kidder gave the following results:

| | |
|---|---|
| Silica | 42.53 |
| Alumina | 16.83 |
| Iron oxide | 5.66 |
| Lime | 5.66 |
| Magnesia | 4.82 |
| Potash | 3.70 |
| Soda | 4.10 |
| Combined water* | 15.76 |

J. B. Weems, analyst.

*Combined water and carbon dioxide.

The limestone and magnesia are believed to be confined argely to the hard fossiliferous layers, and on that account the magnesia percentage could be easily reduced by wasting the ndurated bands.

In the vicinity of Decorah, in Winneshiek county, the Galena-Trenton is well developed and is non-dolomitic. At the ice house in the west part of town, the section exposed on the south bank of the Oneota river is as follows:

| | | Feet. |
|---|---|---|
| 4. | Limestone, massive when first exposed; weathered into thin bands displaying either a cuboidal or a decidedly concretionary facies; 25 feet exposed but thickens greatly toward the upland | 25 + |
| 3. | Limestone, argillaceous, with numerous shaly partings; mixed zone | 10 |
| 2. | Shale, greenish-gray, strongly calcareous and with argillaceous limestone bands | 20 |
| 1. | Limestone, hard, compact, flaggy; exposed at this point | 4 |

The beds dip to the west at a low angle and form an abrupt escarpment on the south bank of the river for some distance west of the above section.

Samples were selected from numbers 2, 3, and 4 of the section and analyzed. The analyses are given below:

| | 2. | 3. | 4. |
|---|---|---|---|
| Silica | 17.45 | 14.53 | 3.86 |
| Alumina and Iron oxide | 9.15 / 5.75 | 6.49 | 2.54 |
| Calcium carbonate | 54.07 | 72.89 | 91.19 |
| Magnesium carbonate | 4.11 | 1.03 | 0.84 |
| Alkalies as $K_2O$ | 2.53 | 0.36 | .00 |
| Sulphur trioxide | 1.67 | 0.48 | .00 |
| Combined water | 5.57 | 3.75 | 2.14 |
| Moisture | 0.25 | 0.15 | 0.05 |

L. G. Michael, analyst.

value of "machine peat" compared with good coal, it is not probable that this form of fuel will become widely used in the state. It seems certain, however, that a farmer having good peat deposits on his land or, better still to insure a wider demand for the fuel, a number of men could jointly install a small "machine peat" fuel plant, at a cost of a very few hundred dollars, and by operating such a plant during the autumn months they could supply a local demand for domestic fuel at a price very much below that at present paid for coal. While this form of peat is slightly inferior to good coal, yet it possesses a higher heating value than wood and, burned in peat stoves, would prove a satisfactory and very economical domestic fuel.

### PEAT BRIQUETTES.

In the more approved peat briquetting plants the peat is dug, pulverized and spread by a mechanical excavator, and is dried in the air to a water content of 30 to 45 per cent. The air-dried peat is then passed through a disintegrator in which the fragments are beaten into small bits and the tissues thoroughly crushed in order to facilitate the further liberation of moisture. This broken peat is then conveyed to the dryer in which it is subjected to artificial heat until not more than 12 to 15 per cent of moisture remains. From the drying pan it is carried to the hopper and cooled, and thence conveyed to the briquetting press. Two general types of presses are in use; one consists of an open tube, and the other of a closed die resting on a solid base. The latter type has proved the most satisfactory. Pressure of 11 to 13 tons per square inch is applied, and the resulting briquettes are dense and solid, and have a heating efficiency equal to the best grades of Iowa coal.* Peat briquettes absorb moisture readily and hence must be kept dry.

In Holland the cost of production of peat briquettes is from $2.00 to $2.15 per ton. At Welland and Beaverton, Ontario, peat briquettes are being made for about $1.50 per ton, and are sold for $3.50 per ton at the works.† At the Beaverton plant "cut peat" was found to be a cheaper fuel for use under the boiler and dryer than good wood at $1.30 per cord.

The Beaverton is one of the oldest and most successful peat briquetting plants in America. Estimate of the cost of the complete equipment of a peat fuel plant, similar to the Beaverton, with a capacity of 3,000 tons of briquettes per year, running ten hours a day, or 6,000 to 7,000 tons when working continuously, is furnished as follows:‡

| | |
|---|---|
| Briquette press, die or mould type | $ 2,500.00 |
| Dryer | 1,350.00 |
| Breaker or disintegrator | 400.00 |
| Excavator, including motor | 600.00 |
| Generator, tram car, motor and tracks | 1,200.00 |
| Engine and boiler, 50-horsepower | 2,000.00 |
| Shafting, belts and conveyors | 700.00 |
| Buildings (brick) | 1,500.00 |
| Sundries | 200.00 |
| Total | $10,450.00 |

*For the calorific value of a number of Iowa coals see this Bulletin, pp 25-27; and also Iowa Geol. Surv., Vol. XIV, p. 37).
†13th Report Ontario Bureau of Mines, p. 27, 1904
‡12th Report Ontario Bureau of Mines, p. 225, 1903.

## THE NIAGARA LIMESTONE.

Professor T. E. Savage, in his report on the Geology of Fayette county reports the non-dolomitic character of the Niagara limestone exposed in northern Fayette county. The sections near Auburn Mills were revisited, samples collected and analyses made. The results are tabulated below with a number of analyses of Maquoketa shales exposed in the immediate vicinity and other portions of Fayette county.

| | 1. | 2. | 3. | 4. | 5. | 6. |
|---|---|---|---|---|---|---|
| Silica | 49.60 | 0.68 | 11.95 | 33.82 | 7.55 | 18.31 |
| Alumina | 6.36 | 0.50 | 2.80 | 7.83 | 3.43 | 3.60 |
| Iron oxide | 6.25 | | | 1.92 | | |
| Lime carbonate | ..... | 98.52 | 84.80 | ..... | 78.69 | 73.48 |
| Lime | 22.45 | ..... | ..... | 31.73 | | |
| Magnesium carbonate | ..... | ..... | 0.45 | ..... | 2.40 | 3.10 |
| Magnesia | 0.20 | ..... | ..... | 1.52 | | |
| Soda | 0.35 | ..... | ..... | 1.82 | | |
| Potash | 0.90 | ..... | ..... | 4.25 | | |
| Moisture | ..... | ..... | ..... | ..... | ..... | 0.08 |
| Loss on ignition | 13.56 | ... | ..... | 15.60 | 6.90 | |
| Sulphur trioxide | 0 37 | ..... | ..... | 1.62 | 0.84 | 1.52 |

L. G. Michael, analyst.

1. Maquoketa shale, Auburn Mills. Average samples.
2. Niagara limestones, Auburn Mills. Average samples.
3. Argillaceous limestone, near Clermont.
4. Shale near Clermont.
5. Natural cement rock near Clermont.
6. Shaly limestone near base of Maquoketa at Elgin.

Auburn Mills is an inland town and while both shale and limestone are exposed in unlimited quantities they are not available commercially at the present time.

## THE DEVONIAN.

### FLOYD COUNTY.

The Cedar Valley limestone and the Lime Creek shales and marls are the only portions of the Devonian included in this investigation. Analyses were made from materials selected from sections exposed at Rockford, Lithographic City, Osage, the "Clay Banks" near Portland, and Mason City.

The beds exposed in the pit of the Cream City Brick and Tile Company near Rockford are as follows:

| | | Feet |
|---|---|---|
| 5. | Marl, highly fossiliferous, grayish yellow above to blue-gray below: upper beds distinctly lighter in color than the lower.... | 12 |
| 4. | Clay shale, blue-gray, appears to be slightly more gritty than Nos. 1 and 2, and is also more pervious; the contact between this zone and No. 2 is stained and is apparently a plane of seepage,.... | 12 to 15 |
| 3. | Iron-stained zone with numerous concretions, variable..... | ½ to 2 |
| 2. | Clay shale, similar to No. 1..... | 6 |
| 1. | Shale, gray-blue, slightly gritty, non-fissile | 12 |

Analyses were made of each member in the above section and the results are as follows:

*Analyses of Rockford shales and marl.*

| | Marl No. 5. | No. 4. | No. 3. | No. 2. * | No. 1. * |
|---|---|---|---|---|---|
| Silica | 19.63 | 23.83 | 50.40 | 49.00 | 46.12 |
| Alumina and Iron oxide | 11 33 | 15.10 | 31.22 | 15.28 / 6.24 | 15.32 / 5.62 |
| Calcium carbonate | 59.14 | 46.57 | 7.68 | | |
| Magnesium carbonate | 4.73 | 1.63 | 5.77 | | |
| Sulphur trioxide | Trace | 3.50 | 1.54 | | |
| Alkalies as $K_2O$ | ..... | ..... | 4.96 | | |
| Combined water | 4.41 | 3.68 | 4.51 | | |
| Moisture | 0 27 | 0.22 | 0.41 | | |

L. G. Michael, analyst.

*Analyzed by E. E. Bugbee.

In 1903 an average sample was selected from the lower portion of the pit and analyzed. The analysis is given below.

| | |
|---|---|
| Silica | 58.33 |
| Alumina | 15.54 |
| Iron oxide | 3.84 |
| Lime | 9.42 |
| Magnesia | 3.03 |
| Potash | 1.19 |
| Soda | 1.76 |
| Combined water | 3.47 |
| Sulphur trioxide | 1.10 |
| Moisture | 0.42 |

J. B. Weems, analyst.

The marl and shales are generously distributed in the vicinity of Rockford, south of Lime creek and west of the Shellrock river. Roadways crossing the low bluffs facing Lime creek

expose both members, and the overburden is thin for some distance back from the stream, in some instances for more than a mile. The Chicago, Rock Island & Pacific railway passes within about one-half mile of excellent outcrops. A spur could be easily extended to the shales and marls as the grades are low. Lime creek separates the railway from the nearest exposures, but the creek could be avoided by making a slight detour.

Pure limestone does not occur in quantity at this point above the water level in Lime creek. An abundance of good limestone outcrops along the Shellrock river at Nora Springs a few miles north. Analyses of the limestone have not yet been made. Two trunk lines, the Chicago, Milwaukee & Saint Paul and the Chicago, Rock Island & Pacific afford good railway facilities. The latter road would furnish a direct connection with the shales at Rockford.

The limestone members are also well developed in the vicinity of Charles City. Samples were carefully selected from the quarry at Lithographic City by Mr. C. L. Webster. The section as determined by Mr. Webster is as follows:

| | | Feet. |
|---|---|---|
| 11. | Soil and drift | 1 |
| 10. | Limestone, lithographic | 5 |
| 9. | Limestone, yellow-gray, friable, coarsely granular and thin bedded | ½ |
| 8. | Limestone, dense, compact; buff to grayish white, thin-bedded | 3½ |
| 7. | Limestone, lithographic, shattered and unevenly bedded; brown, variegated | 1 |
| 6. | Clay parting | 1/6 |
| 5. | Limestone, compact | 1¾ |
| 4. | Clay parting | 1/6 |
| 3. | Limestone, buff to pink, lithographic | 1½ |
| 2. | Limestone, gray, sub-crystalline | ¼ |
| 1. | Limestone, lithographic, dense, exposed | 3 |

An average sample was selected from the above section and analyzed. The analysis is given herewith:

| | |
|---|---|
| Calcium carbonate | 92.85 |
| Magnesium carbonate | 5.31 |
| Iron and alumina | 0.80 |
| Insoluble | 1.60 |

A. O. Anderson, analyst.

The magnesia percentage can undoubtedly be lowered by the elimination of number 9 in the above which appears to be strongly dolomitic.

A short line of railway is about to be extended to the quarries. No shale is known in the near vicinity, at least not nearer

than Rockford in Floyd county, and the "Clay Banks" in Cerro Gordo county.

MITCHELL COUNTY.

Similar beds of limestone extend into Mitchell county. An average sample from the Gable quarry near Osage was analyzed; the results are given below:

| | |
|---|---|
| Calcium carbonate | 90.17 |
| Magnesium carbonate | 1.03 |
| Iron and alumina | 3.82 |
| Insoluble | 2.21 |
| Moisture and organic matter | 2.63 |

A. O. Anderson, analyst.

While the limestone is sufficiently pure for cement here, as in the case of Lithographic City, suitable shales are not available.

CERRO GORDO COUNTY.

The shales and marls exposed in the vicinity of Rockford are believed to be more or less continuous with those exposed at the "Clay Banks" near Portland and at Mason City. Near Lime creek there is very little stripping over the beds, in many cases not sufficient to support a sod. While no outcrops are known directly on the railroads, save at Mason City, numerous outcrops are within easy reach of several trunk lines. At the "Clay Banks" the following section is exposed facing directly on Lime creek, and continuing for a distance of about one mile.

| | | Feet |
|---|---|---|
| 5. | Shale, calcareous or marl; in some places indurated layers appear | 3 |
| 4. | Cap rock, variable in thickness | 1 |
| 3. | Marl, highly fossiliferous; containing occasional hard bands | 20 |
| 2. | Shale, non-fossiliferous, weathered yellow | 10 |
| 1. | Shale, bluish-gray to blue and becoming highly plastic on weathering; non-fossiliferous | 40 |

A hard compact limestone outcrops in the creek and forms the floor upon which the above section rests.

Samples selected from this section were analyzed; the results are given in the table below, the numbers corresponding to the numbers in the section. Three samples were selected from the marl comprising number 3 in the section, of which 3a was taken from the indurated layers.

*Analysis of clay shales and marls from the 'clay banks' near Portland, Cerro Gordo county.*

| | No.1 | No.2 | No 3 | No. 3a | No 3b | No.4 | No. 5 |
|---|---|---|---|---|---|---|---|
| Moisture | 1.21 | 1.00 | 0.73 | 0.35 | 0.75 | 0.68 | 0.93 |
| Combined water | 3.29 | 0.76 | 2.72 | 0.17 | 3.67 | 2.44 | 2.04 |
| Silica | 49.93 | 50.15 | 20.26 | 5.36 | 20.82 | 7.59 | 27.26 |
| Alumina | 20.23 | 19.68 | 11.28 | 3.79 | 11.55 | 5.62 | 19.15 |
| Ferric oxide | 4 32 | 4.08 | 2.76 | 1.20 | 2.76 | 1.56 | 4.32 |
| Lime | 6.70 | 9.78 | 31.42 | 48.18 | 30.01 | 44.34 | 16.47 |
| Magnesia | 2.79 | 2.26 | 3.44 | 2.70 | 4.01 | 3.22 | 2.23 |
| Sulphur trioxide | 1.14 | 1.18 | 2.09 | 1.02 | 1.19 | 0.51 | 1.11 |
| Soda | 2.17 | 1.03 | 0.50 | 0.27 | 0.72 | 0.29 | 1.55 |
| Potash | 2.25 | 1.62 | 1.09 | 0.46 | 1.41 | 0.48 | 2.20 |
| Carbon dioxide | 6.05 | 8.54 | 23.56 | 35.73 | 23.05 | 33.39 | 12.59 |

J. B. Weems, analyst.

The stripping is of variable thickness but usually thin. The limestone at the base rises toward Portland, occurring in both banks of Lime creek, and aggregating fifteen to twenty feet in thickness with practically no covering. No analyses were made but the section appears to be identical with the upper portion of the limestone section exposed at Mason City. The "Clay Banks" are about equally distant from the Iowa–Dakota division of the Chicago, Milwaukee & Saint Paul and the Fox Lake division of the Chicago and Northwestern railways.

At Mason City, the shales and marls appear some distance to the south and west of Lime creek while there is an almost continuous section of limestone along Willow, Calamus and Lime creeks. The section at the quarries of the Mason City Lime and Cement Company is as follows:

| | | Feet |
|---|---|---|
| 3. | Limestone, Stromatapora zone, which in weathering presents a concretionary appearance | 10-15 |
| 2. | Limestone, white, compact and brittle, in rather thin beds | 12 |
| 1. | Dolomite or at least dolomitic limestone; sub-crystalline, brown, exposed above low water in Lime creek | 10 |

The several members in the above section disappear a short distance east but reappear at Portland. They form almost an unbroken section to the northwest and can be traced to Fertile, in Worth county, some fifteen miles distant.

The shales and marls are exposed south and west of the city. Immediately west of the Fairgrounds, along a small creek, the following section is exposed:

| | Feet |
|---|---|
| 2. Marl, weathered yellow | 12 |
| 1. Shale clay, blue-gray, becoming very plastic when weathered. Exposed | 20 |

The shales are known to attain a thickness of some forty feet southwest of the city in the pits of the brick companies. Analyses were made of all of the members in the above sections and the results are given below.

| | 1. | 2. | 3. | 4. | 5. | 6. |
|---|---|---|---|---|---|---|
| Silica | 35.23 | 54.56 | 51.95 | 0.72 | 0.63 | 54.64 |
| Alumina | 21.09 | 30.62 | 18.34 | 0.91 | 0.71 | 14.62 |
| Ferric oxide | | | 7.56 | | | 6.45 |
| Calcium carbonate | 32.84 | 4.10 | 4.14† | 94.22 | 97.48 | 9.21 |
| Magnesium carbonate | 3.94 | 2.13 | 3.26† | 1.32 | 0.99 | 6.09 |
| Alkalies as $K_2O$ | ..... | 2.32 | 4.12 | ..... | ..... | 5.89 |
| Sulphur trioxide | 3.11 | 2.30 | 2.76 | 0.98 | | |
| Combined water | 4.26 | 4.19 | 7.49* | 2.46 | ..... | 3.74 |
| Moisture | 0.12 | 0.30 | 0.42 | 0.05 | 0.51 | 0.85 |

* Combined water and carbon dioxide.
† These percentages are of oxides instead of carbonates.

1. Marl from exposure west of Fairgrounds. L. G. Michael, analyst.
2. Shale from exposure west of Fairgrounds. L. G. Michael, analyst.
3. Shale from pit of American Brick and Tile Company. J. B. Weems, analyst.
4. Stromatopora limestone, quarry of Mason City Lime & Cement Company. L. G. Michael, analyst.
5. Mason City White Limestone, quarry of Mason City Lime & Cement Company. A. O. Anderson, analyst.
6. Shale from pit of Mason City Brick and Tile Company. G. E. Patrick, analyst.

The marls and shales are known to extend over a large area and are easily reached, as there is but little cover over them. Both the limestones and the shales are within easy reach of the railways which enter the city.

It will be noted that all of the Devonian limestones analyzed are essentially pure, carrying very small percentages of magnesia and sulphur. All of the shales are calcareous and grade insen-

sibly into marls. They carry from less than two to more than eight per cent of magnesium carbonate, and are comparatively low in sulphur trioxide. Calculating the magnesium as an oxide it reduces to from less than one to about four per cent, not enough when blended with the limestone to be a serious consideration in the manufacture of Portland cement. All of the shales are comparatively low in silica and high in alumina and iron, a much more important consideration than the question of sulphur and magnesia. According to the best authorities the shales used in the manufacture of Portland cement, when used with pure limestones, should carry at least 55 per cent of silica, preferably 60 or 70 per cent, and in any event at least twice the sum of the alumina and ferric oxide. *Eckel states that the composition in terms of silica, alumina and ferric oxide should fall within the following limits.

$$\frac{SiO_2}{Al_2O_3 + Fe_2O_3} > 2 \quad : \quad \frac{SiO_2}{Al_2O_3 + Fe_2O_3} < 3.5$$

Now it is apparent from a casual inspection of the analyses that the silica ratio for the various shales and marls varies from less than 2 to about 2.8 per cent, and in order to secure the best composition the addition of silica may be found desirable.

## THE LOWER CARBONIFEROUS.

Deposits belonging to the Kinderhook, Saint Louis and Coal Measures are included in the present investigation. The Kinderhook was observed at various points in Hardin and Humboldt counties, but samples were collected and analyzed from only the latter county. The Saint Louis was investigated only at Livermore in Humboldt county, while the Coal Measures were studied at a number of points in addition to those already mentioned.

### WEBSTER COUNTY.

Highly siliceous shales are available along the Des Moines river between Fort Dodge and Lehigh in Webster county, and along the Iowa Central railway in Hardin county. An average sample was selected from the pit of Johnston Brothers Clay Works at Kalo, in Webster county. The analysis is given below:

| | |
|---|---|
| Silica | 70.20 |
| Alumina | 16.70 |
| Iron oxide | 4.00 |
| Lime | 0.28 |
| Magnesia | 0.63 |
| Potash | 1.75 |
| Soda | 1.39 |
| Combined water | 3.70 |
| Sulphur trioxide | 0.82 |
| Moisture | 0.53 |

* Cements, Limes and Plasters, page 305, 1905.

The Chicago Great Western railway reaches the shales of the Des Moines river district, though not the pit from which the sample was selected for analysis.

A sample selected from the pit of the Eldora Pipe and Tile Company in Hardin county gave the following results:

| | |
|---|---|
| Silica | 72.09 |
| Alumina | 16.24 |
| Iron oxide | 1.08 |
| Lime | 0.48 |
| Magnesia | 0.48 |
| Potash | 1.08 |
| Soda | 0.77 |
| Sulphur trioxide | 0.14 |
| Combined water | 5.18 |
| Moisture | 2.46 |

The Atlas Cement Company ship a portion of the shales used at their Hannibal, Mo., plant a distance of sixty miles, while a considerable portion is mined on the premises. Siliceous shale can no doubt be found at other points within reach of Mason City, Rockford and Portland.

### HARDIN COUNTY.

Beds low in magnesia constitute the lower portion of the Kinderhook section in Iowa Falls and in the quarries of the Ellsworth Stone Company and the Barber Asphalt Company. They are overlain by from ten to thirty feet of sub-crystalline dolomite in addition to a thin veneer of alluvium and surface wash. West of Iowa Falls, from the Ivanhoe quarries to Alden, the dolomitic beds have been removed along the Iowa river and the limestone appears almost continuously in one or both banks of the river, rising from five to twenty feet above low water level. The overburden amounts to but little near the river but thickens greatly in the bluffs. A representative section at Alden on the river front is as follows:

| | | Feet. |
|---|---|---|
| 3. | Alluvium, drift and wash | 3 |
| 2. | Limestone, more or less evenly bedded; similar to No. 1; a marly or shaly band separates Nos. 1 and 2 generally | 12 |
| 1. | Limestone, light-gray, hard sub-crystalline and oolitic texture. The upper surface somewhat undulating while the lower 4 feet shows cross-bedding | 5 |

The beds are much rifted and shattered. Individual layers rarely four or five inches in thickness dip to the southwest. The entire assemblage disappears up the river about the corporate limits of the town. The Iowa Falls branch of the Chicago & Northwestern railway runs near the line of outcrop of these beds. Satisfactory shales are not easily accessible in the near vicinity. At the "Honestone quarries" west of Iowa Falls the Coal Measure shales appear in the north bank of the river. The section is appended herewith:

| | | Feet. |
|---|---|---|
| 5. | Drift | 40–90 |
| 4. | Sandstone, fine grained, slightly argillaceous, forming a projecting ledge | 2–5 |
| 3. | Shale, arenaceous, blue-gray and but slightly indurated. Certain hard layers appear throughout the section | 30 |
| 2. | Shale, blue, fissile; in some places almost black | 15 |
| 1. | Limestone, dolomitic, weathered, exposed above the water level | 1+ |

No analyses have yet been made of either the limestone or the shale. It is believed, however, that the limestone is essentially free from magnesia and sulphur, and that the shale number 2 in the Honestone section is highly siliceous and probably of suitable composition to blend with the limestone in the manufacture of Portland cement. It could be produced, however, only by mining. Further investigation is necessary to demonstrate the merits of both limestone and shale. The shale beds could be reached by extending the switch which now reaches the plant of the Iowa Falls Brick and Tile Company.

### HUMBOLDT COUNTY.

The Kinderhook limestone beds outcrop near the Minneapolis and Saint Louis railway in the southern part of the city of Humboldt and present an almost continuous exposure on the river for more than a mile. The same beds outcrop near the Chicago

and Northwestern railway north of the city, and near Rutland about five miles to the northwest. The section exposed below the dam in Humboldt is given below:

| | | Feet |
|---|---|---|
| 4. | Alluvial wash, variable in thickness; on top of terrace about | 3 |
| 3. | Limestone, oolitic, rather coarse grained, gray to white | 10 |
| 2. | Limestone, compact, gray white, a gradation from No. 1 but fewer fossils present and apparently less brecciated | 2 |
| 1. | Limestone, brecciated and filled with casts of fossils, chiefly brachiopods; very compact and brittle in outcrop; bedding planes not apparent. Exposed above low water | 4 |

The section rises toward the town and the oolite probably shows a greater thickness than is indicated in the above section. All of the beds dip perceptibly up stream. An average sample was taken from the above section and analyzed. The result is given below:

| | |
|---|---|
| Insoluble | 0.50 |
| Iron oxide and alumina | 1.12 |
| Calcium carbonate | 97.20 |
| Magnesium carbonate | 2.00 |
| Total | 100.82 |

Analyzed by A. O. Anderson, from sample collected by C. M. Morgan.

To the west, just across the Humboldt county line, near Gilmore, extensive limestone beds, belonging to the Saint Louis, appear near the surface. According to McBride in his Humboldt county report the Gilmore section is as follows:

| | | Feet |
|---|---|---|
| 10. | Alluvium, surface soil, etc | 6 |
| 9. | Coarse sand and gravel | 3 |
| 8. | Bowlder clay, much weathered | 2–4 |
| 7. | Limestone, coarse-grained, crystalline | 20 |
| 6. | Shale, blue, with clay and limestone; fossiliferous | 2 |
| 5. | Limestone, lithographic, inclined to angular fracture | 1½ |
| 4. | Limestone, fine-grained, heavy-bedded and non-fossiliferous | 3 |
| 3. | Limestone, shaly with few fossils | 1 |
| 2. | Limestone, fossiliferous, coarse-grained | 1 |
| 1. | Limestone, lithographic | 2 |

An analysis was made of the principal member in the above section and is given herewith:

| | |
|---|---|
| Silica | 0.32 |
| Alumina and iron | |
| Calcium carbonate | 99.62 |
| Water and undetermined | 0.06 |

J. B. Weems, analyst.

A casual inspection of the analysis shows the limestone to be almost absolutely pure. The quarries are within easy reach of the Des Moines and Ruthven division of the Chicago, Rock Island and Pacific railway.

## THE COAL MEASURES.

Extensive limestone beds are to be found in the upper Coal Measures in southwestern Iowa. In Madison county the Bethany limestone forms an almost continuous escarpment diagonally across the county from Peru by way of Winterset to Earlham.

Near Earlham two quarry companies have operated extensively, and are directly connected with the main line of the Rock Island railway. The sections exposed are as follows:

QUARRY SECTION, EARLHAM LAND COMPANY.

Located about one and one-half miles south of railway station in Earlham

| | | Feet. |
|---|---|---|
| 4. | Loess and drift, of variable thickness | 10 to 14 |
| 3. | Limestone, in regular beds, with shale parting near the middle | 9 |
| 2. | Limestone, less evenly bedded than the above, hard and brittle | 6 |
| 1. | Sandstone, calcareous and shaly, exposed | |

QUARRY SECTION OF S. A. ROBERTSON.

Located about two miles east of railway depot in Earlham.

| | | Feet. |
|---|---|---|
| 7. | Loess and drift, variable | 2 to 8 |
| 6. | Limestone, gray to buff, evenly bedded | 2 |
| 5. | Limestone, irregularly bedded, with some cherts | 3 |
| 4. | Limestone, evenly bedded, becoming shaly near the middle | 4 |
| 3. | Limestone, shattered, unevenly bedded, cherty | 1½ |
| 2. | Limestone, rather evenly bedded above, and unevenly bedded below. Hard and compact but in thin ledges | 6 |
| 1. | Sandstone, calcareous and shaly, exposed | |

is designed for washing finely pulverized material, while the latter will successfully wash coal composed of pieces up to one and one-half inches in diameter. The modified Stewart jig gave good satisfaction, and seems very well adapted to most kinds of coal.

Charges of Iowa coal for coking tests were first washed, and the results of this process appear in the following analyses:

*Iowa No* 1.—Lump and fine coal from mine No. 2, Anchor Coal Company, Laddsdale, Iowa.

About five tons of this coal were washed for a coking test, but the coal was not tried in a raw condition, and consequently the coking test affords no clue to the improvement made by washing. The change is shown by the chemical analyses.

*Analyses showing effect of washing Iowa No. 1 coal.*

| | Car sample. | Washed coal for coking. |
|---|---|---|
| Ash | 16.0 | 10.25 |
| Sulphur | 5.03 | 4.61 |

*Iowa No.* 2. —Run-of-mine coal from mine No. 6, Mammoth Vein Coal Company, Hamilton, Iowa.

About 5½ tons of coal were washed for a coking test. The reduction of impurities effected by washing was not great, as shown by the following analyses:

*Analyses showing effect of washing Iowa No. 2 coal.*

| | Car sample. | Washed coal for coking. |
|---|---|---|
| Ash | 15.22 | 10.28 |
| Sulphur | 4.66 | 3.93 |

*Iowa No.* 3.—Lump coal from mine No. 4, Gibson Coal Mining Company, Altoona, Iowa.

About 4½ tons of this coal were washed for a coking test. The improvement in the quality of the coal effected by washing is shown in the following analyses:

*Analyses showing effect of washing Iowa No. 3 coal.*

| | Car sample. | Washed coal for coking. |
|---|---|---|
| Ash | 14.01 | 8.03 |
| Sulphur | 6.15 | 4.55 |

*Iowa No.* 4.—Lump coal from mine No. 3, Centerville Block Coal Company, Centerville, Iowa.

A charge consisting of about 4½ tons of this coal was washed for coking purposes. The results were not so satisfactory as those obtained on other samples from this state. The analyses are given below:

*Analyses showing effect of washing Iowa No. 4 coal.*

| | Car sample. | Washed coal for coking. |
|---|---|---|
| Ash | 10.96 | 7.14 |
| Sulphur | 4.26 | 3.59 |

*Iowa No.* 5.—Run-of-mine coal from mine No. 1, Inland Fuel Company, Chariton, Iowa.

A charge consisting of nearly 5 tons of this coal was washed for a coking test, but the coal did not coke, although the washing was fairly successful in reducing the impurities, as shown by the following analyses:

*Analyses showing effect of washing Iowa No. 5 coal.*

| | Car sample. | Washed coal for coking. |
|---|---|---|
| Ash | 12.63 | 7.93 |
| Sulphur | 3.19 | 2.28 |

The improvement of the Iowa coal by washing was most marked in samples No. 3 and No. 5. In the former the ash was reduced 6.98 per cent, and the amount of sulphur was lowered 1.60 per cent. In some samples the improvement by washing was slight.

The removal of impurities from coal by means of washing is accomplished by the sorting action of water upon particles fairly uniform in size, but differing in their specific gravity. In some states there is a growing practice on the part of the operators to wash their coal, especially that which is to be burned into coke. The cost of washing does not exceed 6 or 7 cents per ton.

It is possible that some of the Iowa coal would be sufficiently improved by washing to make that process profitable. For most purposes it would be very desirable to reduce the sulphur content of the coal as low as possible. The efficiency of washing in accomplishing this result depends largely upon the form in which the sulphur of the coal exists, and whether this undesirable constituent is disseminated through the coal in a finely divided condition.

In Iowa coal the sulphur commonly occurs either in the form of gypsum (hydrous calcium sulphate) or as pyrite or marcasite (iron disulphide). The specific gravity of coal is variable, but is somewhat less than 1.5. That of gypsum is about 2.31, while that of iron disulphide

The Coal Measure shales outcrop at numerous other points in and about the city, although equally good sections free from stripping within easy reach of a railroad are not known.

## THE CRETACEOUS.

Limestone, chalk and shale are abundant in the Cretaceous beds of northwestern Iowa. No extensive deposits of limestone and chalk, easily obtainable, are known however. As a rule both occur in comparatively thin beds and are deeply buried by the drift and other worthless materials. No samples were collected or analyses made of these materials during the present investigation.

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